Glass and Ceramics, Vol. 68, Nos. 9 – 10, January, 2012 (Russian Original, Nos. 9 – 10, September – October, 2011)

SCIENCE FOR CERAMIC PRODUCTION

UDC 666.77:666.3-12:620.193.4

CHEMICAL STABILITY OF POROUS PERMEABLE CERAMIC WITH ALUMINOSILICATE BINDER IN ACIDIC AND ALKALINE REAGENTS

B. L. Krasnyi,[1, 2] V. P. Tarasovskii,[1] and A. B. Krasnyi[1]

Translated from *Steklo i Keramika*, No. 10, pp. 15 – 17, October, 2011.

The effect of H_2SO_4, HCl, NaOH, and Na_2CO_3 concentrations on the chemical stability of porous permeable ceramic based on electrocorundum and aluminosilicate binder is investigated. It is shown that the chemical stability of porous ceramic with the experimental chemical composition depends on the type and concentration of the reagent solution used for the tests. Porous ceramic is least chemically stable in concentrated sodium hydroxide solutions and most stable in soda ash solutions at any concentration. The acid resistance of porous ceramic is lowest in 90 – 80% sulfuric acid solutions.

Key words: ceramic, porous, electrocorundum, aluminosilicate binder, acid resistance, alkali resistance.

A ceramic is said to be chemically stable if it withstands prolonged exposure to various chemicals in the liquid or gaseous state. Ceramics materials are often the only suitable materials for working in contact with corrosive media, especially at elevated temperatures.

Because liquid and gaseous substances interact chemically along the entire contact surface of a chemical substance and a ceramic, including the pores in the ceramic, the porosity of chemically stable articles must be as low as possible [1]. As a rule, the published data on the chemical stability of ceramic materials pertains to material with minimal porosity [2 – 3].

Over the last 10 years the industrial demand for porous ceramic articles has increased considerably and their applications have also expanded, for example, articles made of porous permeable ceramic are used to purify liquids and gases, including corrosive ones heated to high temperatures [4].

[1] Science and Technology Center Bakor, JSC, Shcherbinka, Moscow Oblast, Russia.
[2] E-mail: krasnyntcbacor@mail.ru.

This has made research on the properties of porous permeable ceramic in different liquid corrosive media topical, because aside from the action of a corrosive medium at the technological stage of filtering modern filtering equipment includes a stage of regeneration (restoration of the filtering capacity) of filtering elements, during which a filtering element is exposed to a corrosive fluid flow in a direction opposite to the flow of corrosive liquid during filtering. In a number of cases a corrosive liquid with pH opposite to that of the medium being purified is used.

The test samples were prepared from porous permeable ceramic 60 mm in diameter and 20 mm thick. The specific pressing pressure used on the samples was 30 MPa.

The granular fill consisted of F240 electrocorundum, produced at RUSAL Boksitogorsk, JSC (TU 3988-064-00224450–94). The chemical composition of the electrocorundum and technological aluminosilicate binder are presented in Table 1. The ratio of the components in the mix for forming the samples corundum : aluminosilicate

TABLE 1. Chemical Composition of Electrocorundum and Aluminosilicate Binder

Material	Content, wt.%							
	Al_2O_3	SiO_2	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O
F240 electrocorundum	99.77	0.03	–	0.015	–	–	–	0.18
Aluminosilicate binder	17.35	67.28	1.02	4.020	2.88	2.89	1.12	3.44

0361-7610/12/0910-0327

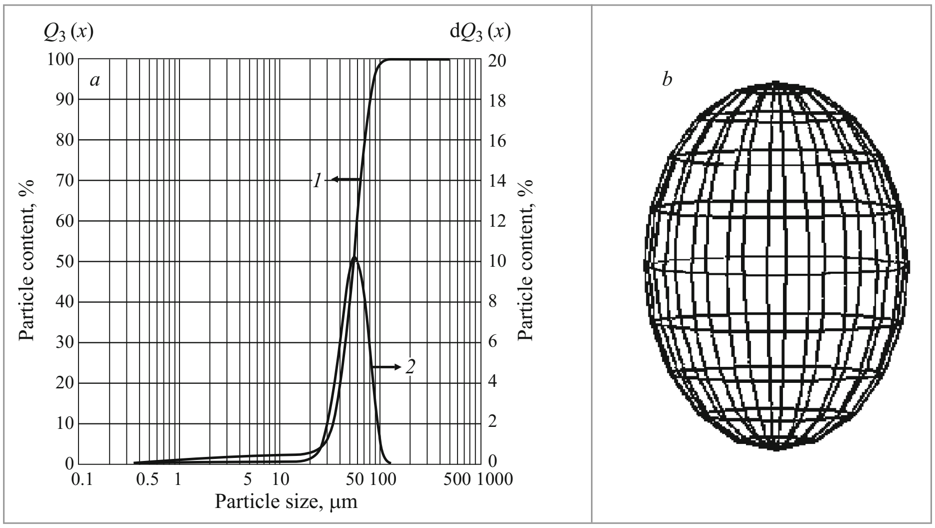

Fig. 1. Properties of electrocorundum powder (Analyzette 22 laser particle analyzer, Fritsch GmbH Company, Germany): *a*) integral (*1*) and differential (*2*) particle distribution curves for electrocorundum powders; *b*) particle shape of electrocorundum powders.

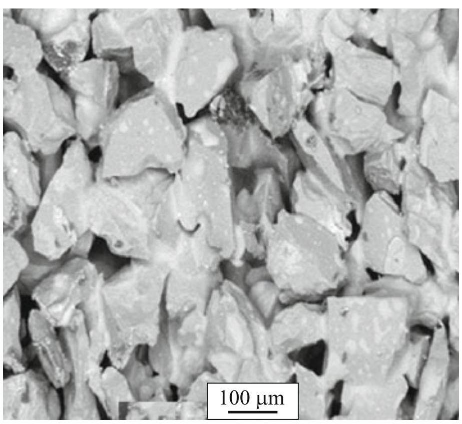

Fig. 2. Microstructure of porous permeable ceramic (SEM JSM-6490LV, Jeol Company, Japan).

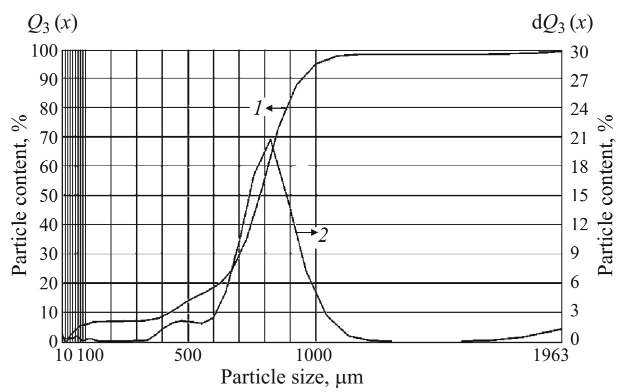

Fig. 3. Granule distribution of powder prepared for corrosion resistance tests (the powder was obtained by comminuting a porous ceramic sample): *1*, *2*) integral and differential curves, respectively.

binder was (%[3]) 85 : 15. A KV 2097 binder manufactured by the firm Zscimmer&Schwarz GmbH (Germany) was used as a temporary technological binder. It was introduced in amount 10% above 100% with respect to the mix.

The need to secure the strength of the articles at low firing temperatures dictates the technological binder composition.

The particle-size properties of the electrocorundum powder are presented in Fig. 1.

Analysis of the particle distribution curves for the electrocorundum powder show three separate points (d_{10} = 34.420 μm, d_{50} = 54.754 μm, d_{90} = 80.019 μm), which make it possible to characterize individual powder and to compare powders with one another. The electrocorundum powder chosen to fabricate samples of porous permeable ceramic can be characterized as a powder with a narrow particle-size distribution. Such powders make it possible to obtain packing with maximum porosity, which is often very important for fabricating articles made of porous permeable ceramic.

The samples used in the present investigations were fired for 2 h at temperature 1300°C.

Physico-Technical Properties of Samples Made from F-240 Porous Permeable Ceramic

Ceramic type	F-240
Apparent density, g/cm³	2.19
Open porosity, %	41.0
Ultimate compression strength, MPa	52.1
Ultimate strength under diametric compression, MPa	16.0
Ultimate bending strength, MPa	35.7
Gas permeability, μm²	2.5
Water permeability, μm²	8.9
Effective pore size, μm	23.4

Figure 2 shows the post-firing microstructure of porous permeable ceramic.

The acid and alkali resistance of porous ceramic was determined following GOST 473.1–81 using procedures (MI 11773998-1–2004 and MI 11773998-2–2004) developed and used at the Science and Technology Center Bakor, JSC.

[3] Here and below, content by weight.

TABLE 2. Chemical Stability of Porous Ceramic in Sulfuric Acid with Different Concentration

Parameter	H_2SO_4 content, wt.%											
	93.64	90.0	85.0	80.0	77.0	70.0	60.0	50.0	25.0	10.5	5.5	2.5
Acid resistance, %	98.8	96.88	95.35	97.29	97.75	98.06	98.45	98.52	98.33	98.12	98.21	98.00

TABLE 3. Chemical Stability of Porous Ceramic in Hydrochloric Acid with Different Concentration

Parameter	HCl content, wt.%						
	36.0 (chemically pure)	30.0	20.0	15.0	10.0	5.0	0.5
Acid resistance, %	98.02	98.10	98.24	97.95	97.82	97.0	98.70

The method used in the present work to determine the chemical stability is based on determining ratio of the mass of the comminuted ceramic article after it has been treated with acid (alkali) to the mass of the same article (powder) before it has been treated with acid (alkali). The mass of the sample was 1.0000 g; the particle size of the comminuted material ranged from 0.8 to 1.0 mm; the H_2SO_4 concentration was 98% while the NaOH was 35% water solution; the powder with the chemical reagent was boiled for 1 h in a flask with a reflux condenser.

Figure 3 shows the properties of the porous ceramic powder granules used for testing chemical stability.

The chemical stability of the porous ceramic was studied in H_2SO_4, HCl, NaOH, and Na_2CO_3 with different concentrations. The results of the studies are presented in Tables 2 – 5.

The following conclusions can be drawn from the results of these studies.

The chemical stability of the porous ceramic chosen for testing chemical composition depends on the chemical composition and concentration of the solution of the corrosive liquid used for the tests.

The porous ceramic is chemically least stable in a concentrated solution of sodium hydroxide.

The porous ceramic is chemically most stable in soda ash solutions with any concentration.

The porous ceramic is least acid resistant in a sulfuric acid solution with mass content in the range 90 – 80%. According to [5] 85% sulfuric acid is characterized by the maximum refractive index of light, viscosity, and heat of mixing and the minimum electric conductivity. This concentration of sulfuric acid corresponds to a crystal hydrate with the minimal amount of water — oxonium salt $H_3O \cdot HSO_4$. The high dissolving power is probably also explained by a physical-chemical characteristic of 85% sulfuric acid.

TABLE 4. Chemical Stability of Porous Ceramic in a Sodium Hydroxide Solution with Different Concentration

Parameter	NaOH content, wt.%					
	50.0	35.0	20.0	10.0	5.0	1.0
Alkali resistance, %	84.20	91.25	95.02	97.35	98.08	98.93

TABLE 5. Chemical Stability of Porous Ceramic in a Soda Ash Solution with Different Concentration

Parameter	Na_2CO_3 content, wt.%			
	17.7	10.0	5.0	1.0
Chemical stability, %	99.91	99.80	99.88	99.97

REFERENCES

1. I. Ya. Guzman (ed.), *Chemical Technology of Ceramics* [in Russian], RIF Stroimaterialy, JSC, Moscow (2003).
2. V. A. Lavrenko and Yu. G. Gogotsi, *Corrosion of Building Ceramic* [in Russian], Metallurgiya, Moscow (1989).
3. B. L. Krasnyi, V. P. Tarasovksii, E. V. Rakhmanova, and V. V. Bondar', "Chemical stability of ceramic materials in acids and alkalis," *Steklo Keram.*, No. 10, 22 – 24 (2004); B. L. Krasnyi, V. P. Tarasovksii, E. V. Rakhmanova, and V. V. Bondar, "Chemical resistance of ceramic materials in acids and alkalis," *Glass Ceram.*, **61**(9 – 10), 337 – 339 (2004).
4. B. L. Krasnyi, V. P. Tarasovskii, and A. B. Krasnyi, "Use of new ceramic materials — one of the most important factors in increasing the cost-effectiveness, energy efficiency, and ecological safety of enterprises," *Novye Ogneupory*, No. 8, 10 – 21 (2010).
5. B. V. Nekrasov, *Principles of General Chemistry* [in Russian], Khimiya, Leningrad (1971).